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(71) Sökande                      Volvo Aero Corp, Trollhättan SE  
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Juris Rozitis

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## Title:

An outlet nozzle and a method for manufacturing it

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## TECHNICAL FIELD

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The present invention relates to the field of outlet nozzles for use in liquid fuel rocket engines, according to the preamble of the subsequent claim 1. Also, the invention relates to a method for manufacturing these nozzles. The invention is especially intended for use in respect of cooled outlet nozzles for rocket motors driven by liquid fuel.

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## BACKGROUND OF THE INVENTION

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During operation, a rocket nozzle is subjected to very high stresses, for example in the form of a very high temperature on its inside (in the order of magnitude of 800 °K) and a very low temperature on its outside (in the order of magnitude of 50 °K). As a result of this high thermal load, stringent requirements are placed upon the choice of material, design and manufacture of the outlet nozzle. At least there is a need for effective cooling of the outlet nozzle.

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Cooling is provided by attaching individual lengths of tubing on the inside surface of the nozzle. The geometry of each tube is such that it must conform to the conical or parabolic shape of the nozzle. Additionally, the entire inside surface of the nozzle must be covered to prevent "hot spots" which could result in premature failure of the nozzle. Each nozzle has a diameter ratio from the aft or large outlet end of the nozzle to the

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forward or small inlet end of the nozzle. Typical diameter ratios range from 2:1 to 3:1.

5 According to a previously known method of manufacturing a cooled outlet nozzle, rectangular tubes of constant cross section made from nickel-based steel or stainless steel are used, which tubes are arranged parallel with another and are welded together.

10 The tubes are helically wound such that they form an angle of helix in relation to the longitudinal axis of the nozzle, which angle increases progressively from the inlet end of the nozzle to its outlet end to form a bell shaped nozzle wall. The rocket engine exhausts flowing  
15 along the inside surface of such nozzle having helically arranged tubes result in an angled reaction force creating a roll momentum on the rocket that has to be compensated for by some additional means. These additional means often lead to increased weight and  
20 increased flow resistance. Having long channels without any increase in cross section will also affect the coolant flow resistance negatively.

#### SUMMARY OF THE INVENTION

25 An object of the present invention is to provide a nozzle and a method for manufacturing it, which avoids the problems described above. This is achieved by means of the nozzle according to the invention, which is characterized in that it comprises at least two longitudinally arranged sections and that there is a shift between a positive and  
30 a negative channel angle in the transition from one section to an adjacent section. As a result of the

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invention, it is possible to reduce the roll momentum created by the helical tube channels.

5 According to an advantageous embodiment of the invention, the different angles of the cooling channels in the nozzle sections are adapted to quench reaction forces originating from exhausts flowing past the channels. In this manner, it is possible to avoid the roll momentum completely.

10 According to another embodiment of the invention, each cooling channel extends helically with respect to the longitudinal axis of the nozzle.

15 According to one embodiment of the invention, the channels in each section have a constant cross section along their length.

20 Alternatively, the cross sectional area of the channels of two adjacent nozzle sections may be different. In this embodiment, the cross sectional area of the nozzle channels is preferably larger for a downstream nozzle section than for an upstream nozzle section.

25 A method according to the invention is characterized in the steps of joining a plurality of tubular channels to form a first section of the outlet nozzle in which the channels have an angle of helix in relation to the longitudinal axis of the nozzle, joining a plurality of tubular channels to form a second section of the outlet nozzle in which the channels have opposite angles of helix in relation to the longitudinal axis of the nozzle, and

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joining said sections to form a composite outlet nozzle having continuous cooling channels.

5 BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be further described in the following, in a non-limiting way with reference to the accompanying drawings in which:

10 FIG 1 is a side view showing a nozzle according to the invention,

FIG 2 is a longitudinal section through a joint between two sections, shown in larger scale and before welding, and

15 FIG 3 shows the joint according to FIG 2, after welding.

20 DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a diagrammatic and somewhat simplified side view of an outlet nozzle 10 which is produced according to the present invention. The nozzle is intended for use in rocket engines of the type which uses a liquid fuel, for example liquid hydrogen. The working of such a rocket engine is previously known per se and is therefore not described in detail here. The nozzle 10 is cooled with the aid of a cooling medium which is preferably also used as fuel in the particular rocket engine. The invention is however not limited to outlet nozzles of this type but can also be used in those cases in which the cooling medium is dumped after it has been used for cooling.

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30 The outlet nozzle is manufactured with an outer shape that is substantially bell-shaped. Thus, the nozzle 10 forms a body of revolution having an axis of revolution 11 and a cross section which varies in diameter along said axis.

The nozzle in figure 1 comprises three longitudinally arranged sections 10a, 10b, 10c. It is possible to have a smaller or a larger number of these sections.

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The nozzle wall of each section is a structure comprising a plurality of mutually adjacent, tubular cooling channels 12 helically extending substantially in parallel to each other from the inlet end of the section to its outlet end.

10

Rectangular tubes of constant cross section made from nickel-based steel, stainless steel or other heat resistant materials may be used for manufacturing the sections. In this process, the tubes are arranged helically, in parallel with one another and are welded together. The angle of helix may increase progressively from the inlet end 13 of the nozzle section to its outlet end 14 to form a bell-shaped nozzle wall. The tubes are welded to each other, preferably at the outside by laser welding. The inside of the nozzle is not welded, which means that the gaps may open up when the nozzle is operating, as the thermal cycle is reversed. The maximum thermal stress cycle is therefore limited.

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The tubes 12 in adjacent sections are oriented so that there is a shift between a positive and a negative channel angle in the transition from one section to an adjacent section. Thus, the tube channels in two adjacent sections have opposite angles of helix in relation to the longitudinal axis 11 of the nozzle.

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Figure 2 shows an axial joint of two sections before welding that allows for welding from the outside. For this

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purpos , a notch 15 has been made at the radial outside of the tube ends of each section. The notches 15 make it possible for the laser beam to reach the inner remote parts of the tubes for fusing them together. Then it is possible to join the sides of the rectangular tubes. Finally, as shown in figure 3, a ring 16 is applied over the joint and welded to bridge the gap between the two adjoining nozzle sections.

10 The use of two or more sections in the outlet nozzle makes it possible to change the cross sectional area of the tubes at each axial joint. For example, the radial height of the cross section could be increased to provide more flow area and to reduce the pressure drop in the cooling channels. The restart of the tubes in the transition from one section to the next following section increases the flow area for the constant tube cross section. Only a small number of restarts are needed to reduce the pressure drop to be acceptable for closed engine cycles.

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20 Distribution manifolds are needed at the joints to insure pressure and flow distribution.

25 In the upstream end of the nozzle, it is desirable to keep the cross section small to provide the needed heat flux to reduce the material temperature. Here, the tube thickness could be thinned down still providing the pressure capacity. Thinner walls lead to lower material temperature that increases the cyclic life of the nozzle. In the downstream end of the nozzle, it is desirable to have a large flow area to minimize the pressure drop. The wider tubes needs thicker material to maintain the pressure capacity. This goes hand in hand with needs for a stiff

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nozzl structure for withstanding th side load, ext rnal  
pressure and vibration.

5 The inside of a finished nozzle is provided with small  
helical grooves. In the case of unidirectional winding,  
the friction of the flame creates a reaction momentum that  
normally would have to be counteracted with some  
additional means. By shifting the angle of helix in  
10 accordance with the invention, the roll momentum can be  
counteracted without resorting to additional means. In the  
case of expander cycle rocket engines, the increased  
friction leads to more heat being transferred to the  
coolant and that the turbo-machinery is supplied with more  
power.

15 Before welding the tubes to each other, all the sides of  
the tube are accessible. The side facing the flame and  
part of the tube sides facing adjacent tubes may be coated  
with copper. This will enhance heat transfer from the  
20 parts of the tube not directly exposed to the rocket  
flame. This leads to a reduced material temperature in the  
load carrying structure.

25 The invention is not limited to the above-described  
embodiments, but several modifications are possible  
within the scope of the following claims. For example,  
the joining of two sections may be performed differently  
than described.



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## CLAIMS

5 1. An outlet nozzle (10) for use in a liquid fuel  
rocket engine, said nozzle forming a body of revolution  
having an axis (11) of revolution and a cross section  
which varies in diameter along said axis, and having a  
wall structure comprising a plurality of mutually adjacent  
10 cooling channels (12), helically extending substantially  
in parallel from the inlet end (13) of the nozzle to its  
outlet end (14),

c h a r a c t e r i z e d i n

15 that the nozzle (10) comprises at least two longitudinally  
arranged sections (10a, 10b) and that there is a shift  
between a positive and a negative channel angle in the  
transition from one section to an adjacent section.

20 2. A nozzle according to claim 1,

c h a r a c t e r i z e d i n

that the different angles of the cooling channels (12) in  
the nozzle sections (10a, 10b) are adapted to quench  
reaction forces originating from exhausts flowing past  
said channels.

25 3. A nozzle according to claim 1 or 2,

c h a r a c t e r i z e d i n

that each cooling channel (12) extends helically with  
respect to the longitudinal axis (11) of the nozzle (10).

30 4. A nozzle according to any one of claims 1-3,

c h a r a c t e r i z e d i n

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that the channels in each section (10a, 10b) have a constant cross section along their length.

5        5.        A nozzle according to any one of claims 1-4,  
c h a r a c t e r i z e d   i n  
that the cross sectional area of the channels (12) of two adjacent nozzle sections (10a, 10b) is different.

10       6.        A nozzle according to claim 5,  
c h a r a c t e r i z e d   i n  
that the channel cross sectional area is larger for a downstream nozzle section than for an upstream nozzle section.

15       7.        A nozzle according to any one of claims 1-6,  
c h a r a c t e r i z e d   i n  
that the channels (12) have a rectangular cross section.

20       8.        A method for manufacturing an outlet nozzle (10) for  
use in a liquid fuel rocket engine, said nozzle forming a body of revolution having an axis (11) of revolution and a cross section which varies in diameter along said axis, and having a wall structure comprising a plurality of mutually adjacent cooling channels (12), helically  
25       extending substantially in parallel from the inlet end (13) of the nozzle to its outlet end (14),  
c h a r a c t e r i z e d   i n the steps of

30              joining a plurality of the tubular channels (12) to  
form a first section (10a) of the outlet nozzle (10) in which the channels has an angle of helix in relation to the longitudinal axis (11) of the nozzle,

             joining a plurality of tubular channels (12) to  
form a second section (10b) of the outlet nozzle (10) in

which the channels have opposite angles of helix in relation to the longitudinal axis of the nozzle, and

joining said sections (10a, 10b) to form a composite outlet nozzle (10) having continuous cooling channels (12).

9. A method according to claim 8, characterized in that the said joining is realised by means of laser welding and that the tubular channels (12) are joined by welding at the outside of the nozzle.

10. A method according to claim 8 or 9, characterized in forming the tubular channels (12) by means of tubes having a rectangular cross section.

11. A method according to claim 10, characterized in the step of providing the meeting edges of sections to be joined with notches (15) at the outside, to enable welding the remote part of the tubular channels from the outside of the nozzle (10).

12. A method according to claim 11, characterized in the steps of applying a ring shaped element (16) to bridge the notch area, and welding said element to the meeting channel ends.

**ABSTRACT**

An outlet nozzle and a method for providing an outlet  
nozzle (10) for use in a liquid fuel rocket engine. The  
nozzle forms a body of revolution having an axis (11) of  
revolution and a cross section that varies in diameter  
along said axis. The nozzle has a wall structure  
comprising a plurality of mutually adjacent cooling  
channels, helically extending substantially in parallel  
from the inlet end (13) of the nozzle to its outlet end  
(14). The nozzle comprises at least two longitudinally  
arranged sections (10a, 10b). A shift between a positive  
and a negative channel angle in the transition from one  
section to an adjacent section balances any roll momentum  
generated by friction of rocket exhausts against the  
nozzle wall.

(Fig. 1)

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Huvudfaxen Kasson

